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The Effects of Drop Jump Height on Post-Activation Performance Enhancement at Different Ambient Temperatures

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Abstract: This study aimed to determine whether drop jump height will affect the post-activation performance enhancement (PAPE) effect at room temperature (RT) and low temperature (LT) conditions. Twelve male strength-trained males participated in this study. Prior to warm-up, subjects underwent a 30 min period of environmental adaptation. Different warm-up protocols were used at different ambient temperatures to help subjects achieve a level of muscle activity and body temperature similar to their daily training. After the pre-test, each subject participated in six experimental sessions at either RT or LT conditions, respectively, which were separated by at least 72 h and conducted at the same time of day to control for circadian influences on metabolism. After the conditioning activities, vertical jump (VJ) performance was re-tested at 4 min, 8 min, and 12 min of passive recovery to assess transient potentiation effects. Under RT conditions, 60 cm and 90 cm drop jumps could induce PAPE, with the PAPE effect being most significant at 4 min ($p < 0.01$) and 8 min ($p < 0.01$), respectively, while a 30 cm drop jump could not induce PAPE. Under LT conditions, 30 cm and 90 cm drop jumps could not induce PAPE, and VJ performance gradually declined over time ($p < 0.01$). However, although a 60 cm drop jump could not induce PAPE, VJ performance was not affected by LT at 8 min and declined at 12 min ($p < 0.05$). This study demonstrated that 60 cm and 90 cm drop jumps can be used to induce PAPE at RT conditions. LT can impair PAPE induction, while a 60 cm drop jump can be utilized for warm-up at LT conditions to counteract the effects of LT on athletic performance.

Keywords: ambient temperature; room temperature; low temperature; post-activation performance enhancement; drop jump height

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Citation: Wu, W.; Chen, Z.; Chen, C.; Xue, D.; Lv, Y.; Yu, L. The Effects of Drop Jump Height on Post-Activation Performance Enhancement at Different Ambient Temperatures. *Appl. Sci.* **2023**, *13*, 10346. https://doi.org/10.3390/app131810346

Academic Editors: Hanatsu Nagano and René Schwesig

Received: 14 June 2023
Revised: 5 September 2023
Accepted: 14 September 2023
Published: 15 September 2023

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1. Introduction

Post-activation performance enhancement (PAPE) is a physiological phenomenon that leads to a short-term improvement in strength and power performance due to prior muscle activation [1,2]. Factors influencing PAPE include contraction form (concentric, eccentric, isometric, and plyometric), training intensity, training volume (number of sets, repetitions, and rest intervals), subject characteristics (strength, muscle fiber type, and training experience), and subsequent type of explosive activity performance (running and jumping) [3–5]. Following a conditioning activity protocol, two states of muscle fatigue and potentiation coexist [6], and the net balance between fatigue and potentiation may influence the subsequent performance. The rest interval used may determine which is superior, fatigue or potentiation, and whether enhanced performance is achieved at different rest intervals. Although the effect of recovery time on subsequent performance needs further study, previous studies have shown that the optimal rest interval is generally between 4 and 12 min [7,8]. Currently, there are no consistent results regarding the peak point of PAPE [8,9]. Studies have shown that jump exercises under additional load can induce PAPE and that the drop jump is an effective means of inducing PAPE [10]. In addition, drop jump

height can have an effect on the induction and maintenance of PAPE [11–13], and there are no consistent results regarding the optimal height of drop jumps [14–16]. It is necessary to fully consider factors such as gender, age, the pattern of landing on one or both feet, and the training level of the subject. A previous study showed that identifying complex training variables based on the individual characteristics of athletes can significantly improve athletic performance [17]. The rate at which muscles are stretched during exercise and the rate of the excitation–contraction coupling during eccentric–concentric movements is critical [18]. Therefore, the time from landing to takeoff is crucial in drop jumps. Muscle stretch-shortening cycles (SSC) of the stretch reflex can recruit more motor units involved in contraction to increase muscle strength and power [19]. Therefore, an appropriate drop height will accelerate the rate of eccentric contraction to concentric contractions, thereby maximizing the short-term effects of PAPE on explosive power.

In competitive sports, important events are held at different times of the year. For example, in preparation for the Summer and Winter Olympic Games, athletes need to train at different ambient temperatures. Ambient temperature can have an impact on athletic performance (such as strength, endurance, speed, agility, and flexibility) and training effects (such as drop jump), and by adapting to the ambient temperature, athletes can achieve optimal training results. The effects of high temperatures on athletic performance are most pronounced during prolonged submaximal exercise, resulting in decreased performance [20]. Ali et al. [21] showed that training in a cold, dry environment resulted in decreased performance due to lower temperatures and drying of the lower respiratory tract. However, it has also been reported that training at an ambient temperature of about 11 °C improves performance in long-term moderate-intensity exercise [22]. The ambient temperature in the Winter Olympic Games is usually between −5 °C and 8 °C. Competing at such temperatures requires athletes to train at similar temperature conditions in their daily training. Therefore, the effects of low temperature (LT) on the athlete's body must be fully considered in order to better guide training. Studies have shown that the body's proprioception, resistance and tolerance to stressors, and defensive responses can be enhanced due to cold stimulation at LT conditions [23], resulting in improved athletic performance. However, cold stimulation can also reduce muscle responsiveness and control, especially the ineffective work of the lower limbs [24]. Castellani et al. [25] showed that the negative effect of LT on athletic performance was mainly reflected in a decrease in aerobic capacity. Likewise, strength levels are reduced during LT exposure, mainly due to a decrease in thermoregulatory function caused by a decrease in muscle temperature. Although sprint performance did not appear to be affected during acute LT (6.1 °C) exposure, a significant decrease in vertical jump (VJ) performance was observed compared to the control group (17.2 °C) [26].

Therefore, it is important to determine how the effects of LT on athletic performance can be counteracted by training and how the PAPE "window period" can be used to achieve greater enhancement than the fatigue effect. This study aimed to determine whether drop jump height will affect the PAPE effect at room temperature (RT) and LT conditions.

2. Methods

2.1. Study Design

A randomized crossover study design was used to investigate the acute effects of drop jumps from different heights on VJ performance at RT and LT conditions. In this study, subjects completed six experimental trials consisting of a standardized warm-up, a baseline VJ, and a conditioning activity of three sets of ten drop jumps. After performing one of the 6 conditions (A: 30 cm drop jump at RT (temperature: 25.83 ± 0.55 °C; humidity: 40–60%); B: 30 cm drop jump at LT (temperature: 4.10 ± 0.46 °C; humidity: 40–60%); C: 60 cm drop jump at RT; D: 60 cm drop jump at LT; E: 90 cm drop jump at RT; F: 90 cm drop jump at LT), VJ performance was re-tested after 4 min, 8 min, and 12 min of passive recovery to profile transient potentiation effects. All subjects were instructed to maintain a normal lifestyle and diet and were requested to arrive at the laboratory at least 2–3 h after eating.

2.2. Participants

Twelve strength-trained males (mean age: 19.00 ± 1.71 years; mean height: 180.00 ± 3.93 cm; mass: 69.47 ± 4.73 kg; BMI: 21.43 ± 1.10 kg/m^2) with previous experience in plyometric training volunteered to participate in this study. All subjects met the following inclusion criteria: (a) no potential medical problems or a history of ankle, knee, or back pathology that would compromise their participation or performance in the study, (b) at least 2–3 years of strength training experience, and (c) able to squat at least 1.5 times their body weight. The sample size in this study was based on previous studies that used a similar study design and number of subjects [27,28]. All subjects were fully informed of the procedures, possible risks, and purpose of the study and were instructed to abstain from tobacco, caffeine, alcohol, and vigorous exercise for 24 h prior to the study. The study protocol was approved by the Ethics Committee of Beijing Sport University, and all procedures were carried out in accordance with the recommendations of the Declaration of Helsinki. All participants gave written informed consent in accordance with the Declaration of Helsinki. Descriptive characteristics of the study subjects can be viewed in Table 1.

Table 1. Participants' physical characteristics (n = 12).

	Mean ± SD
Age (years)	19.00 ± 1.71
Height (cm)	180.00 ± 3.93
Weight (kg)	69.47 ± 4.73
Body mass index (kg/m^2)	21.43 ± 1.10

2.3. Procedures

One week prior to the start of the study, participants underwent a familiarization session to become familiar with the drop jump protocols and testing procedures. Subjects were requested to arrive at the laboratory between 16:00 and 18:00 to avoid any possible effects of circadian rhythms on neuromuscular responses and athletic performance [27]. Prior to warm-up, subjects underwent a 30 min period of environmental adaptation. Different warm-up programs were used at different ambient temperatures to help subjects achieve a level of muscle activity and body temperature similar to their daily training. Warm-up programs can be viewed in Table 2. After the pre-test, each subject participated in six experimental sessions at either RT or LT, respectively, which were separated by at least 72 h and conducted at the same time of day to control for circadian influences on metabolism. After the conditioning activities, VJ performance was re-tested at 4 min, 8 min, and 12 min of passive recovery to assess transient potentiation effects. The humidity was maintained between 40% and 60%, and temperature and humidity were measured using a thermos-hygrometer (Deli Group Co., Ltd., Ningbo, China). The experimental procedure is presented in Figure 1.

Table 2. Warm-up programs for RT and LT conditions.

	RT	**LT**
Jogging	5 min	10 min
Muscle activation	Shoulder circles: 1 set × 12 reps Mountain climber: 1 set × 18 reps Single leg glute bridges: 1 set × 12 reps Superman: 1 set × 8 reps Squat: 1 set × 8 reps	Shoulder circles: 1 set × 18 reps Mountain climber: 1 set × 24 reps Single leg glute bridges: 1 set × 18 reps Superman: 1 set × 8 reps Squat: 1 set × 8 reps
Dynamic stretching	Inchworm: 1 set × 8 reps 90/90 for hips: 1 set × 8 reps Lunge walk: 1 set × 8 reps Walking knee lift: 1 set × 8 reps	Inchworm: 1 set × 8 reps 90/90 for hips: 1 set × 8 reps Lunge walk: 1 set × 8 reps Walking knee lift: 1 set × 8 reps

Table 2. *Cont.*

	RT	LT
Motor-skill integration Neural activation	Vertical jump: 1 set × 6 reps High knees: 1 set × 8 s	Vertical jump: 1 set × 6 reps High knees: 1 set × 8 s

Note: RT, room temperature; LT, low temperature; reps, repetitions.

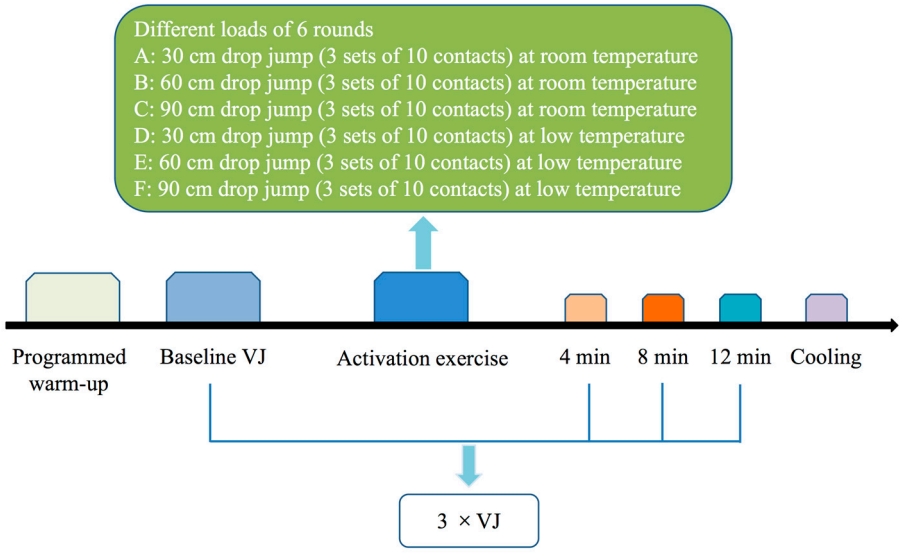


Figure 1. The experimental design.

2.4. Vertical Jump Test

Vertical jumping height was assessed using the jump-and-reach test as described in previous studies [29,30]. Subjects were instructed to stand on a flat surface with their feet positioned shoulder-width apart. They were then directed to execute a countermovement jump, commencing from a standing position, transitioning into a semi-squat position, and then jumping as high as possible with free arms, including an arm swing and reach, to touch the vanes. Each subject was given three attempts, and their highest jump was recorded and used for statistical analysis.

2.5. Statistical Analyses

Data were presented as mean ± standard deviation (SD). Normality was checked using the Shapiro–Wilk test. To assess training-related effects on VJ performance, a three-way repeated-measure ANOVA was conducted with ambient temperature, jump height, and resting time as factors. The Greenhouse–Geisser adjustment was applied where appropriate. Cohen's d was used as the effect size (ES) estimation with strengths interpreted as follows: trivial (0–0.2), small (0.2–0.6), moderate (0.6–1.2), large (1.2–2.0), and very large (>2.0) [31]. Experimental data were analyzed using the IBM SPSS statistical software package (version 25.0, IBM, Chicago, IL, USA). The level of significance was set at $p < 0.05$.

3. Results

Three-way repeated-measure ANOVA revealed an interaction between ambient temperature, jump height, and resting time ($F_{(6,66)} = 3.146$, $p = 0.039$), indicating that jump height at different ambient temperatures may significantly affect VJ performance.

3.1. The Effect of Drop Jump Height on PAPE at RT Conditions

As shown in Table 3 and Figure 2a,b, under RT conditions, there was an interaction effect between drop jump height and resting time ($F_{(6,66)} = 7.257$, $p = 0.002$), indicating that drop jump height may significantly affect the induction and maintenance of PAPE.

Compared with the pre-test, there was no significant difference in VJ performance at a 30 cm drop jump after 4 min (ES, 0.06, 95% CI (−1.18, 1.18), $p = 1.000$), 8 min (ES, 0.01, 95% CI (−1.01, 1.51), $p = 1.000$), and 12 min (ES, −0.09, 95% CI (−0.58, 2.25), $p = 0.660$). However, VJ performance after 4 min (60 cm, ES, 0.57, 95% CI (−4.78, −2.20), $p < 0.001$; 90 cm, ES, 0.37, 95% CI (−4.10, −0.90), $p = 0.002$) and 8 min (60 cm, ES, 0.55, 95% CI (−4.51, −1.99), $p < 0.001$; 90 cm, ES, 0.47, 95% CI (−5.75, −0.75), $p = 0.009$) of 60 cm and 90 cm drop jumps were significantly higher than the pre-test, and the PAPE effect was most significant at 4 min and 8 min, respectively. However, compared with the pre-test, there was no significant difference in VJ performance at 60 cm and 90 cm drop jumps after 12 min (60 cm, ES, 0.20, 95% CI (−1.70, −0.63), $p = 0.160$; 90 cm, ES, 0.19, 95% CI (−2.73, 0.23), $p = 0.123$), suggesting the disappearance of PAPE. In summary, under RT conditions, jump height had a significant effect on VJ performance, with the 60 cm and 90 cm drop jumps inducing PAPE, while the 30 cm drop jump did not induce PAPE.

Table 3. Comparisons of vertical jump heights over the distinct resting times after drop jump training at different ambient temperatures.

	Drop Jump Height	Pre (cm)	4 min (cm)	8 min (cm)	12 min (cm)	Effect Size (95% Confidence Interval)		
						4 min vs. Pre	8 min vs. Pre	12 min vs. Pre
RT	30 cm	302.50 ± 5.97	302.83 ± 5.34	302.58 ± 5.60	302.00 ± 5.39	0.06 (−1.18, 1.18)	0.01 (−1.01, 1.51)	−0.09 (−0.58, 2.25)
	60 cm	302.33 ± 5.94	305.83 ± 6.31 **	305.58 ± 5.79 **	303.50 ± 5.93	0.57 (−4.78, −2.20)	0.55 (−4.51, −1.99)	0.20 (−1.70, −0.63)
	90 cm	302.67 ± 6.08	305.17 ± 7.51 **	305.92 ± 7.54 **	303.92 ± 7.13	0.37 (−4.10, −0.90)	0.47 (−5.75, −0.75)	0.19 (−2.73, 0.23)
LT	30 cm	302.33 ± 6.69	301.08 ± 6.23 *##	300.75 ± 6.72 *#	300.75 ± 6.97 *#	−0.19 (0.06, 2.44)	−0.24 (−0.11, 3.28)	−0.23 (−0.60, 3.76)
	60 cm	302.33 ± 6.54	302.17 ± 6.00 ##	301.42 ± 6.24 ##	300.92 ± 6.67 *##	−0.03 (−1.01, 1.34)	−0.14 (−0.23, 2.07)	−0.21 (−0.14, 2.97)
	90 cm	302.67 ± 6.23	301.08 ± 6.52 **##	300.75 ± 7.07 **##	300.42 ± 5.33 **##	−0.25 (0.25, 2.92)	−0.29 (0.32, 3.52)	−0.39 (−0.08, 4.42)

Note: RT, room temperature; LT, low temperature. Compared to pre-test, * $p < 0.05$; ** $p < 0.01$. Compared to RT, # $p < 0.05$; ## $p < 0.01$.

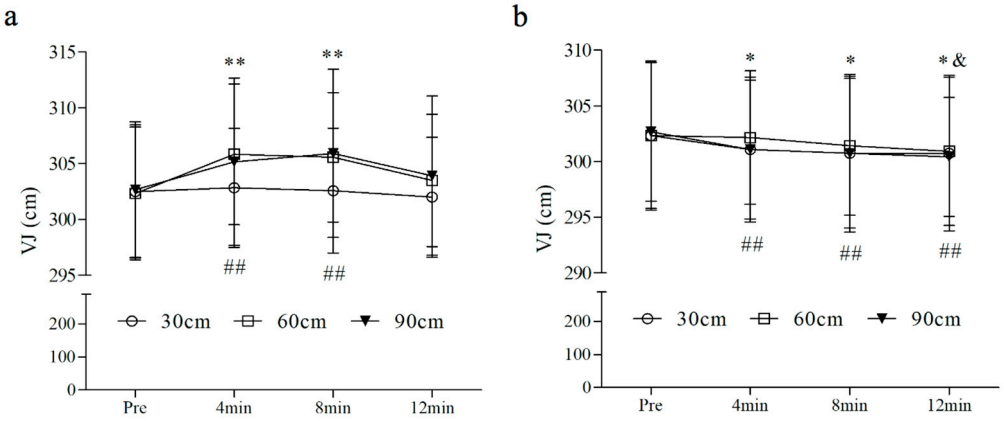


Figure 2. (**a**,**b**) Vertical jump height at the baseline and after completing drop jump training at different ambient temperatures: (**a**) room temperature; (**b**) low temperature. Compared with pre-test, * $p < 0.05$, ** $p < 0.01$; ## $p < 0.01$; & $p < 0.05$.

3.2. The Effect of LT on PAPE

As shown in Table 3 and Figure 2a,b, under LT conditions, there was no interaction between jump height and resting time ($F_{(6,66)} = 0.693$, $p = 0.537$), indicating that jump height had no significant effect on the induction and maintenance of PAPE. VJ performance after 4 min (30 cm, ES, −0.19, 95% CI (0.06, 2.44), $p = 0.001$; 90 cm, ES, −0.25, 95% CI (0.25, 2.92), $p = 0.004$), 8 min (30 cm, ES, −0.24, 95% CI (−0.11, 3.28), $p = 0.000$; 90 cm, ES, −0.29, 95% CI (0.32, 3.52), $p = 0.002$), and 12 min (30 cm, ES, −0.23, 95% CI (−0.60, 3.76), $p < 0.001$; 90 cm, ES, −0.39, 95% CI (−0.08, 4.42), $p < 0.001$) of the 30 cm and 90 cm drop jumps were

significantly lower than the pre-test, indicating that the 30 cm and 90 cm drop jumps failed to induce PAPE, and the performance gradually decline over time. However, there was no significant difference in VJ performance at 4 min (ES, −0.03, 95% CI (−1.01, 1.34), $p = 1.000$) and 8 min (ES, −0.14, 95% CI (−0.23, 2.07), $p = 0.467$) after the 60 cm drop jump, while VJ performance of 12 min was significantly lower than the pre-test (ES, −0.21, 95% CI (−0.14, 2.97), $p = 0.046$), indicating that although the 60 cm drop jump failed to induce PAPE, performance was not affected by LT at 8 min and declined at 12 min. In summary, under LT conditions, PAPE was not induced by drop jumps of different heights.

As shown in Table 3 and Figure 3a–c, compared with RT conditions, there was no significant difference in VJ performance before the 30 cm ($p = 0.438$), 60 cm ($p = 1.000$), and 90 cm ($p = 1.000$) drop jumps at LT conditions, indicating that the preparation activities at LT conditions achieved the same warm-up effect as the RT conditions. However, VJ performance after 4 min (30 cm, $p = 0.003$; 60 cm, $p < 0.001$; 90 cm, $p < 0.001$), 8 min (30 cm, $p = 0.023$; 60 cm, $p < 0.001$; 90 cm, $p < 0.001$), and 12 min (30 cm, $p = 0.032$; 60 cm, $p = 0.001$; 90 cm, $p = 0.004$) of the 30 cm, 60 cm, and 90 cm drop jumps were lower at RT conditions, indicating that LT can significantly affect the induction and maintenance of PAPE, with a decrease in VJ performance at all time points after the 30 cm, 60 cm, and 90 cm drop jumps.

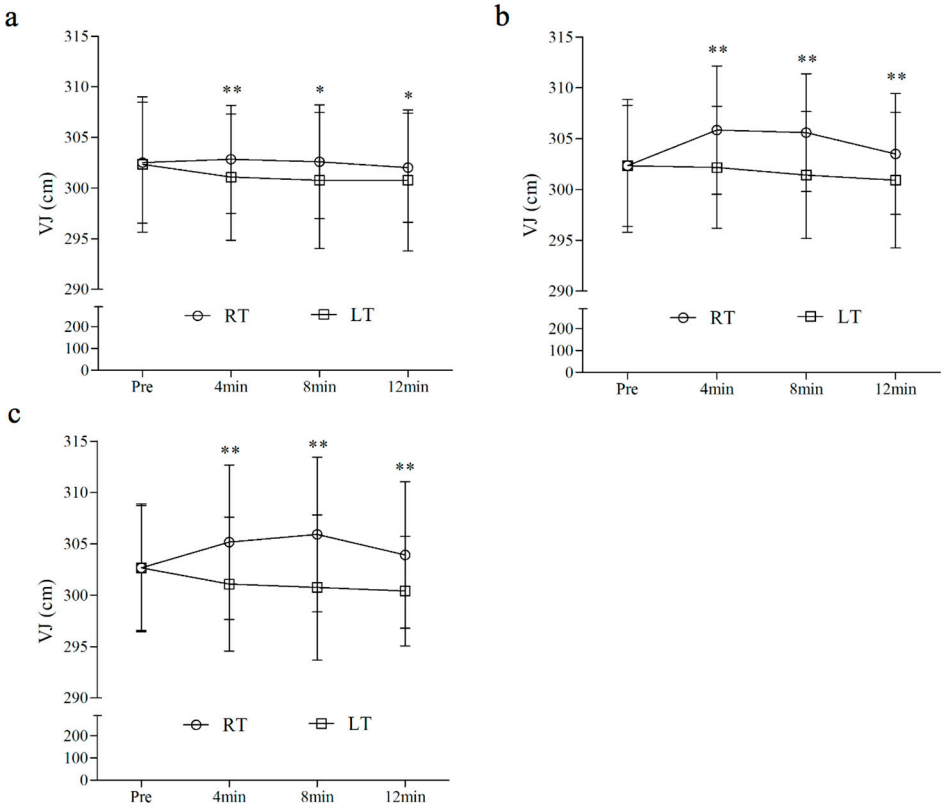


Figure 3. (**a**–**c**) Difference in vertical jump height at RT and LT conditions for the same drop jump height. RT, room temperature; LT, low temperature: (**a**) 30 cm drop jump; (**b**) 60 cm drop jump; (**c**) 90 cm drop jump. Compared with RT conditions, * $p < 0.05$; ** $p < 0.01$.

4. Discussion

The aim of this study was to determine whether drop jump height will affect the PAPE effect at RT and LT conditions. The results showed that under RT conditions, the 60 cm and 90 cm drop jumps induced PAPE, and the PAPE effect was most significant at 4 min and 8 min, respectively, while the 30 cm drop jump did not induce PAPE. Under LT conditions, the 30 cm and 90 cm drop jumps did not induce PAPE, and VJ performance gradually declined over time. However, although the 60 cm drop jump did not induce PAPE, VJ performance was not affected by the LT at 8 min and declined at 12 min.

4.1. The Effect of Drop Jump Height on PAPE at RT Conditions

Studies have shown that drop jump training can be effective in improving rapid strength levels, which is important for sports that emphasize explosive power [32,33]. However, the explosive factor occupies an important place in PAPE. A study by Karampatsos et al. [6] showed that three sets of drop jump training significantly increased the throwing distance of hammer throwers after 1 min, suggesting a significant PAPE effect. Training intensity is the most important factor in inducing PAPE, and different drop jump heights have different effects on PAPE. Wilson et al. [34] showed that induced PAPE was most effective in improving athletic performance at 60–84% one-repetition maximum (1RM) load intensity. A moderate intensity (i.e., 80% 1RM) may result in significant increases in jumping, repetitive changes in direction velocity, and non-repetitive changes in direction velocity in elite male soccer players compared to low-intensity (60% 1RM) and high-intensity (100% 1RM) warm-up protocols [35]. Our results showed that under RT conditions, VJ performance after 4 min and 8 min of 60 cm drop jumps were significantly higher than the pre-test, and the PAPE effect was most significant at 4 min, which was consistent with Tobin et al. [36]. In addition, VJ performance after 4 min and 8 min of a 90 cm drop jump was significantly higher than the pre-test, and the PAPE effect was most significant at 8 min, which was in agreement with the findings of Kilduff et al. [37], where the jumping performance of rugby players was significantly improved 8 min after three sets of an 87% 1RM back squat. However, there was no significant difference in VJ performance at a 30 cm drop jump after 4 min, 8 min, and 12 min. The effect of recovery time after PAPE induction on subsequent performance needs further study. Beato et al. [38] showed that a significant PAPE window period occurred 3–7 min after load stimulation, i.e., the enhancement effect was greater than the fatigue effect. In addition, a study by Kilduff et al. [37] on professional football players showed that PAPE appeared at 8 min and 12 min, while the optimal recovery time occurred at 8 min. Furthermore, Lowery et al. [39] showed that VJ height and output power increased significantly after resistance training at moderate intensity (70% 1RM) and high intensity (93% 1RM), while the PAPE effect was most significant at 4 min.

Previous studies have shown that the fatigue effect is believed to dominate immediately after conditioning activities, but the enhancement effect lasts longer. Therefore, a precise schedule is needed for the improvement of athletic performance, and the enhancement effect can be greater than the fatigue effect if the rest interval is long enough. However, the rest interval should not be too long to avoid a decrease in the enhancement effect [17,40]. In the present study, there was no significant difference in VJ performance at 60 cm and 90 cm drop jumps after 12 min compared to the pre-test. The failure of the PAPE effect to be maintained over 12 min may be due to the enhancement effect being counteracted by the fatigue effect. Many studies have reported the effects of different drop jump heights on training outcomes, and their findings suggest that the optimal drop jump height is not fixed and will exist within a range due to individual differences in athletes [41–43]. In addition, a previous study has shown that the results are highly individualized for each individual, and there is no consistent training intensity or rest interval that increases the vertical jump height the most for all subjects [36]. Therefore, there will be individualized differences in the duration of maintenance of the PAPE effect due to the different training experience and exercise capacity of the subjects, which is consistent with the findings of Villarreal et al. [8], who showed that in all countermovement jump (CMJ) tests after interventions, the PAPE response was significantly higher in the dominant group than the inferior group, with the greatest enhancement effect 6 min after the test in the dominant group and 9 min after the test in the inferior group.

Currently, there is some controversy regarding the choice of optimal height for drop jump training. Some studies have used 40 cm as the optimal drop jump height, while Decker et al. [12] reported that a jump height of 60–80 cm produced greater power than a drop jump height of 40 cm. However, Viitasalo et al. [13] showed that compared to 40 cm, 80 cm drop jump training produced shorter ground contact times, and the vertical ground reaction force was greater. In addition, a previous study has shown that athletes who chose

a height of 80 cm for drop jump training achieved better results at the Gymnastics World Championships than athletes who chose heights of 20 cm, 40 cm, 60 cm, and 100 cm [43].

4.2. The Effect of LT on PAPE

Different ambient temperatures have varying effects on athletic performance, and by adapting to these temperatures, athletes can achieve optimal training results. We next explored whether LT would have an effect on the induction and maintenance of PAPE. Our results showed that under LT conditions, VJ performance after 4 min, 8 min, and 12 min of 30 cm and 90 cm drop jumps were significantly lower than the pre-test. However, there was no significant difference in VJ performance at 4 min and 8 min after the 60 cm drop jump, while VJ performance at 12 min was significantly lower than the pre-test, indicating that under LT conditions, PAPE was not induced by drop jumps of different heights. In addition, compared with RT conditions, VJ performance after 4 min, 8 min, and 12 min of 30 cm, 60 cm, and 90 cm drop jumps were lower than at RT conditions. This may be due to the fact that muscle movement becomes sluggish with the decrease in temperature when a drop jump is performed at LT conditions [43]. This phenomenon can be explained by the results of Bergh et al. [44], who showed a 4.2% decrease in muscle explosive power for every 1 °C decrease in core temperature. In addition, Oksa et al. [45] also showed that muscle temperature decreased at LT conditions, which in turn led to a significant decrease in VJ takeoff time. Furthermore, Ferretti et al. [46] showed that blood flow to the muscles of the lower limbs was significantly reduced after exercise at LT conditions, leading to a decrease in muscle contractile function and impaired athletic performance. At the same time, LT can lead to a decrease in the maximum contraction force of the muscle, while the force–velocity curve can shift to the left, which in turn reduces the rate of force generation during exercise and affects athletic performance [47].

However, under LT conditions, there was no significant difference in VJ performance at 4 min and 8 min after the 60 cm drop jump compared to the pre-test, while VJ performance at 12 min was significantly lower than the pre-test. Combined with the results that PAPE was effectively induced by a 60 cm drop jump at RT conditions and the PAPE effect was most significant at 4 min and was maintained until 8 min, the effect of PAPE induced by a 60 cm drop jump offset the influence of LT on VJ performance. Riera et al. [48] showed that exercise in LT conditions requires additional muscle effort to maintain athletic performance in order for the body to generate sufficient energy to maintain core temperature and compensate for heat loss, and, therefore, the fatigue produced by exercise results in an offsetting enhancement effect. In addition, many studies have shown that the blood lactate concentration is higher during exercise at LT conditions compared to RT conditions [49,50], which suggests that the body provides energy for exercise at LT conditions mainly through anaerobic metabolism. However, anaerobic capacity is affected by LT [51], which can affect athletic performance at LT conditions. In addition, LT may affect the ability of the cardiovascular system to deliver oxygen to working muscles and the ability of metabolism to produce sufficient energy [47]. Furthermore, Ferretti et al. [46] found a significant decrease in muscle temperature in the lower limb after a study on six healthy subjects after prolonged exposure to water below the abdomen at 20 °C. In summary, LT resulted in a decrease in muscle temperature, with the fatigue effect accounting for the dominant, and the enhancement effect was small.

However, PAPE was effectively induced by a 90 cm drop jump at RT conditions, and the PAPE effect was most significant at 8 min, while VJ performance after 4 min, 8 min, and 12 min of 90 cm drop jumps were significantly lower than the pre-test at LT conditions. This may be due to the fact that LT reduces the muscle contractile function. Furthermore, since the PAPE effect was most significant at 8 min, the PAPE effect at 4 min was not sufficient to offset the influence of LT on VJ performance.

4.3. Limitations

This study has several limitations that should be noted. First, the relatively small sample size of this study makes it highly desirable to conduct future studies with larger sample sizes. Second, our observations to date are primarily applicable to strength-trained males, and there is a need to extend observations to cover females, other age groups, and other skill levels. In addition, further studies are also needed on more different drop heights and ambient temperatures to determine the optimal drop height for athletes to benefit from PAPE at different ambient temperatures. Finally, since the participants of this study were not athletes accustomed to training at LT conditions, our findings may not apply to those who are accustomed to training at LT conditions.

5. Conclusions

This study demonstrated that 60 cm and 90 cm drop jumps can be used to induce PAPE at RT conditions. LT can impair PAPE induction, while a 60 cm drop jump can be utilized for warm-up at LT conditions to counteract the effects of LT on athletic performance.

Author Contributions: Conceptualization, L.Y. and W.W.; methodology, W.W. and Z.C.; software, W.W.; validation, C.C. and D.X.; formal analysis, W.W.; investigation, W.W., Z.C., C.C., D.X. and Y.L.; resources, L.Y.; data curation, Y.L.; writing—original draft preparation, W.W. and Z.C.; writing—review and editing, L.Y.; visualization, Y.L.; supervision, L.Y.; project administration, L.Y.; funding acquisition, L.Y. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Key R&D Program of China, grant number 2022YFC3600201, and the Chinese Universities Scientific Fund, grant numbers 2021QN001 and 2022QN015.

Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and was approved by the Ethics Committee of Beijing Sport University (protocol code 2022112H, 16 May 2022).

Informed Consent Statement: Informed consent was obtained from all subjects involved in this study.

Data Availability Statement: The datasets generated during and/or analyzed during the present study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflict of interest.

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